भारतीय मानक
Indian Standard

IS 16352 : 2020

भूकृत्रिम — लाइनिंग के लिए उच्च घनत्व पोलीइथीलीन (एचडीपीई) की ज्योमैम्बरेन — विशिष्टि

(पहला पुनरीक्षण)

Geosynthetics — High Density Polyethylene (HDPE) Geomembranes for Lining — Specification

(First Revision)

ICS 59.080.70

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Geosynthetics Sectional Committee, TXD 30

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Geosynthetics Sectional Committee had been approved by the Textile Division Council.

High density polyethylene geomembranes, are very low permeability synthetic liners used to control fluid or gas migration within soil, rock, earth or any other geotechnical material, as integral part of a manmade product, structure or system. The original use of geomembranes was for the distribution, storage and containment of potable agricultural water supplies. It still remains as an important element of this market, except now it has been broadened to contain a wide variety of liquids.

Geomembranes have become the design choice as part of a cover system due to a variety of factors, such as imperviousness, chemical resistance, inertness to surrounding soils, ease and variety of seaming, mechanical strength and elongation, ease of application and economics, product durability and ageing over the designed life of the containment system.

This standard was first published in the year 2015 and has been revised to incorporate the following major changes:

a) Textures geomembrane (single or double sided) and its requirements have been incorporated.
b) Requirement for hydrostatic resistance has been modified.
c) Test method for UV exposure has been modified.
d) Requirement for stress crack resistance has been modified.
e) BIS certification marking clause has been updated.

The committee has reviewed the provisions of the following International Standard/Other publication referred in this standard and has decided that these are acceptable for use in conjunction with this standard:

International Standard/ Other publication	*Title*
ISO 11357-6 : 2018:	Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)
ASTM D 5885 : 2017	Standard test method for oxidative induction time of polyolefingeosynthetics by high-pressure differential scanning calorimetry

The guidelines and method for installation of HDPE geomembranes is given in Annex N for information only.

The composition of the Committee responsible for the formulation of this standard is given in Annex P.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GEOSYNTHETICS — HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANES FOR LINING — SPECIFICATION

(First Revision)

1 SCOPE

1.1 This standard covers smooth and textured HDPE geomembrane lining for use in canals, ponds, reservoirs, water features (bodies) for seepage control, for lining of landfills, hazardous waste management, solid waste management and industrial effluent for waste containments and for water proofing of large underground civil structures, basement, road underpasses, tunnels, foundation, roofs / terrace.

1.2 The test used to characterize the HDPE geomembrane are intended to ensure good workmanship and quality and are not necessarily adequate for design purposes in view of the importance of environmental factors and specific performance objectives. Tests have been selected primarily with essentially natural aqueous system in mind. Other tests may be necessary to establish chemical resistance and durability under the condition of particular application.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 MATERIAL AND MANUFACTURE

3.1 The HDPE geomembrane shall be suitably manufactured from HDPE granules, which shall be UV stabilized by adding suitable UV stabilizer or carbon black. The finished HDPE geomembrane shall be a three layer structure such that the finished material meets the requirements as given in Table 1 for smooth geomembranesand Table 2 for textured geomembranes (single or double sided).

3.2 If two or more pieces of geomembranes are used, the material shall be joined together by a suitable heat sealing process keeping an overlap of at least 2.5 cm.

4 VARIETY AND TYPES

4.1 Based on the finish, HDPE geomembrane shall be of following varieties:

a) Smooth geomembranes, and
b) Textured geomembranes (Single or double sided).

4.2 Based on the thickness of HDPE geomembrane, the material shall be classified as under:

4.2.1 For smooth geomembranes:

a) *Type I* — Having thickness of 0.50 mm;
b) *Type II* — Having thickness of 0.75 mm;
c) *Type III* — Having thickness of 1.00 mm;
d) *Type IV* — Having thickness of 1.50 mm;
e) *Type V* — Having thickness of 2.00 mm;
f) *TypeVI* — Having thickness of 2.50 mm; and
g) *TypeVII* — Having thickness of 3.00 mm.

4.2.2 For textured geomembranes:

a) *Type I* —Having thickness of 0.75 mm;
b) *Type II* —Having thickness of 1.00 mm;
c) *Type III* —Having thickness of 1.50 mm;
d) *Type IV* —Having thickness of 2.00 mm;
e) *TypeV* — Having thickness of 2.50 mm; and
f) *TypeVI* — Having thickness of 3.00 mm.

5 REQUIREMENTS

The HDPE geomembrane shall conform to the requirements as given in Table 1 for smooth geomembranes and Table 2 for textured geomembranes (single or double sided).

6 DIMENSIONS AND TOLERANCES

The dimensions of HDPE geomembrane when tested by the method given in IS 7016 (Part 1) shall be as agreed to between the buyer and the seller. However, the minimum width of the HDPE geomembrane shall be 5000 mm. A combination of panel width may be used to obtain desired width of geomembrane. Narrow width panels not less than 1000 mm in width may also be used but such pieces shall not exceed 1 piece per roll of finished material of specified width.

7 COLOUR, SURFACE CHARACTERISTICS AND FREEDOM FROM DEFECTS

7.1 The HDPE geomembrane shall be uniform in colour, texture and finish. The colour, unless specified, shall be black. It shall be free from pin-holes and other foreign particles when tested by the method prescribed in Annex M.

7.2 The HDPE geomembrane shall be reasonably free from defects, such as holes, tears or blisters. The edges shall be free of nicks and cuts visible to the naked eye.

8 MARKING

8.1 The HDPE geomembrane shall be supplied in roll form and each roll shall bear a label on which the following information shall be provided with indelible ink:

a) Name and type of the material;
b) Name and/or trade- mark of the manufacturer;
c) Thickness and declared length and width; and
d) Batch No. and date of manufacture.

8.2 BIS Certification Marking

The HDPE geomembrane conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the HDPE geomembrane may be marked with the Standard Mark.

Table 1 Requirements of Smooth HDPE Geomembrane (*Continued*)

(*Clauses* 3.1 *and* 5)

Sl No.	Characteristic	Requirement							Method of Test, Ref to
		Type 1	Type II	Type III	Type IV	Type V	Type VI	Type VII	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Length and width, mm	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	IS 7016 (Part 1)
ii)	Average thickness at a pressure of 2 ± 0.01 kPa, mm, *Min*	0.50	0.75	1.00	1.50	2.00	2.50	3.00	Method A of IS 13162 (Part 3)
iii)	Lowest individual of 10 thickness value	-10 percent	-10 percent	-10 percent	-10 percent	-10 percent	-10 percent	-10 percent	Method A of IS 13162 (Part 3)
iv)	Tensile properties:								Annex B
	a) Yield strength, kN/m, *Min*	7	11	15	22	29	37	44	
	b)Breaking strength, kN/m, Min	14	20	27	40	53	67	80	
	c) Yield elongation, percent, *Min*	12	12	12	12	12	12	12	
	d) Breaking elongation, percent, *Min*	700	700	700	700	700	700	700	
v)	Tear resistance, N, *Min*	63	93	125	187	249	311	374	Annex C
vi)	Puncture resistance, N, *Min*	160	240	320	480	640	800	960	Annex D
vii)	Low temperature crack resistance at minus 30°C±1°C	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	Annex E
viii)	Hydrostatic resistance	No leakage at 10 kg/cm^2	No leakage at 15 kg/cm^2	No leakage at 20 kg/cm^2	No leakage at 30 kg/cm^2	No leakage at 40 kg/cm^2	No leakage at 48 kg/cm^2	No leakage at 55 kg/cm^2	Annex F
ix)	Seam strength, kN/m, *Min*	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	Annex G
x)	Carbon black content, percent	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	IS 2530
xi)	Carbon black dispersion	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	IS 2530

Table 1 (*Concluded*)

Sl No.	**Characteristic**	**Requirement**							**Method of Test, Ref to**
		Type 1	Type II	Type III	Type IV	Type V	Type VI	Type VII	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
xii)	Oxidative induction time (OIT), minutes, *Min*:								
	a) Standard OIT	100	100	100	100	100	100	100	ISO 11357 (Part 6)
	or								
	b) High pressure OIT	400	400	400	400	400	400	400	ASTM D 5885
xiii)	Oven ageing at 85°C, Retention of oxidative induction time (OIT) after 90 days, percent, *Min*:								Oven method of IS 7016 (Part 8), ISO 11357-6 and ASTM D 5885
	a) Standard OIT	55 percent	55 percent	55 percent	55 percent	55 percent	55 percent	55 percent	
	or								
	b) High pressure OIT	80 percent	80 percent	80 percent	80 percent	80 percent	80 percent	80 percent	
xiv)	Retention of breaking strength after UV exposure of 144 h, *Min*	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	Annex H
xv)	Stress crack resistance, h, *Min*	500	500	500	500	500	500	500	Annex J

Table 2 Requirements of Textured (Single or Double Sided) HDPE Geomembrane (*Continued*)

(*Clauses* 3.1 *and* 5)

Sl No.	Characteristic	Requirement						Method of Test, Ref to
		Type I	Type II	Type III	Type IV	Type V	Type VI	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Length and width, mm	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	As agreed ± 1 percent	IS 7016 (Part 1)
ii)	Average core thickness , mm	0.75 (-5 percent)	1.00 (-5percent)	1.50 (-5 percent)	2.00 (-5percent)	2.50 (-5 percent)	3.00 (-5 percent)	Annex K
iii)	Lowest individual of 10 thickness value	-15 percent	-15 percent	-15 percent	-15 percent	-15 percent	-15 percent	Annex K
iv)	Average asperity height , mm, *Min*	0.40	0.40	0.40	0.40	0.40	0.40	Annex L
v)	Tensile properties:							Annex B
	a) Yield strength, kN/m, *Min*	11	15	22	29	37	44	
	b)Breaking strength, kN/m, Min	8	10	16	21	26	32	
	c) Yield elongation, percent, *Min*	12	12	12	12	12	12	
	d) Breaking elongation, percent, *Min*	100	100	100	100	100	100	
vi)	Tear resistance, N, *Min*	93	125	187	249	311	374	Annex C
vii)	Puncture resistance, N, *Min*	200	267	400	534	667	800	Annex D
viii)	Low temperature crack resistance at minus 30°C ± 1°C	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	No specimen shall damage or broken	Annex E
ix)	Hydrostatic resistance	No leakage at 10 kg/cm^2	No leakage at 15 kg/cm^2	No leakage at 25 kg/cm^2	No leakage at 35 kg/cm^2	No leakage at 40 kg/cm^2	No leakage at 45 kg/cm^2	Annex F
x)	Seam strength, kN/m, *Min*	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	85 percent of the original actual fabric strength or unbreakable seam	Annex G
xi)	Carbon black content, percent	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	2.0 to 3.0	IS 2530
xii)	Carbon black dispersion	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	IS 2530

Table 2 (*Concluded*)

Sl No.	Characteristic	Requirement						Method of Test, Ref to
		Type I	Type II	Type III	Type IV	Type V	Type VI	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xiii)	Oxidative induction time (OIT), minutes, *Min*:							
	a) Standard OIT	100	100	100	100	100	100	ISO 11357 (Part 6)
	or							
	b) High pressure OIT	400	400	400	400	400	400	ASTM D 5885
xiv)	Oven ageing at 85°C, Retention of oxidative induction time (OIT) after 90 days, percent, *Min*:							Oven method of IS 7016 (Part 8), ISO 11357-6 and ASTM D 5885
	a) Standard OIT	55 percent	55 percent	55 percent	55 percent	55 percent	55 percent	
	or							
	b) High pressure OIT	80 percent	80 percent	80 percent	80 percent	80 percent	80 percent	
xv)	Retention of breaking strength after UV exposure of 144 h, *Min*	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	85 percent of the original actual fabric strength	Annex H
xvi)	Stress crack resistance, h, *Min*	500	500	500	500	500	500	Annex J

9 CONDITIONING OF TEST SPECIMEN

Unless otherwise specified, all samples shall be conditioned at a temperature of 27 ± 2°C in air for the period of 2 h and relative humidity of 65 ± 5 percent for at least 60 min.

10 SAMPLING

10.1 Lot

In any consignment all the geomembrane roll of same variety and type and dispatched to buyer against one dispatch note shall constitute a lot.

10.2 The number of geomembrane rolls to be selected from a lot shall be in accordance with Table 3. The geomembrane roll shall be selected at random with the use of random number tables (*see* IS 4905).

10.3 The conformity of the lot to the requirements of this standard shall be determined on the basis of the tests on the samples selected from it.

10.4 Criteria for Conformity

The number of rolls selected from the lot shall be tested for various requirements in this standard. If the number of defective rolls or those failing to satisfy any one or more of the requirements is less than or equal to the corresponding permissible number of defective rolls as given in column 4 of Table 3, the lot shall be considered as conforming to the requirement. If the number of defective rolls is more than the corresponding permissible number of defective rolls, the lot shall be considered as not conforming.

Table 3 Sample Size and Criterion for Conformity for Rolls

(*Clauses* 10.2 *and* 10.4)

Sl No. (1)	No. of Rolls in the Lot (2)	No. of Rolls to be Selected (3)	Permissible No. of Defective Rolls (4)
i)	Up to 50	3	0
ii)	51 - 150	5	0
iii)	151 - 300	8	0
iv)	301 and above	13	0

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
2076 : 1981	Specification for unsupported flexible polyvinyl chloride sheeting (*first revision*)
2530:1963	Methods of test for polyethylene moulding materials and polyethylene compounds
4905 : 2015	Random sampling and randomization procedures (*first revision*)
6359 : 1971	Method for conditioning of textiles
7016	Methods of test for coated and treated fabrics
(Part 1) : 1982	Determination of roll characteristics (*first revision*)
(Part 8) : 1975	Accelerated ageing
13162 (Part 3) : 1992	Geotextiles — Methods of test: Part 3 Determination of thickness at specified pressures

ANNEX B

[*Table* 1, *Sl No.* (iv) *and Table* 2, *Sl No.* (v)]

METHOD OF TEST FOR DETERMINING TENSILE PROPERTIES OF GEOMEMBRANES

B-1 This test method covers the determination of the tensile properties of non-reinforced geomembranes in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, and machine speed. This test method can be used for testing materials thickness between 0.25 mm and 6.3 mm.

B-2 APPARATUS

B-2.1 Testing Machine — A testing machine of the constant rate-of-crosshead-movement type and comprising essentially the following:

B-2.1.1 *Fixed Member* — A fixed or essentially stationary member carrying one grip.

B-2.1.2 *Movable Member* — A movable member carrying a second grip.

B-2.1.3 *Grips* — Grips for holding the test specimen between the fixed member and the movable member of the test apparatus can be either a fixed or self-aligning type.

B-2.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the test apparatus. Extreme care shall be taken when this type of grip is used to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the centerline of the grip assembly.

B-2.1.3.2 Self-aligning grips are attached to the fixed and movable members of the test apparatus. This type of grip assembly is such that they will move freely into alignment as soon as any load is applied as long as the long axis of the test specimen will coincide with the direction of the applied pull through the centerline of the grip assembly. The specimens shall be aligned as perfectly as possible with the direction of pull so that no rotary motion will occur in the grips thereby inducing slippage; there is a limit to the amount of misalignment self-aligning grips will accommodate.

B-2.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented as much as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 2.4 mm apart and about 1.6 mm deep, have been found satisfactory for most thermoplastics. Finer serrations have been found to be more satisfactory for harder plastics, such as the thermosetting materials. The serrations shall he kept clean and sharp. Breaking in the grips may occur at times, even when deep serrations or abraded specimen surfaces are used, other techniques shall be used in these cases. Other techniques that have been found useful, particularly with smooth-faced grips, are abrading that portion of the surface the specimen that will be in the grips, and interposing pieces of abrasive cloth, abrasive paper, plastic, or rub coated fabric, commonly called hospital sheeting, between specimen and the grip surface. No. 80 double-sided abrasive paper has been found effective in many cases. An open mesh fabric, in which the threads are coated with abrasive, has been effective. Reducing the cross-sectional area of the specimen may also be effective. The use of special types of grips is sometimes necessary to eliminate slippage and breakage at grips.

B-2.1.4 *Drive Mechanism* — A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, with this velocity to be regulated as specified in **B-6**.

B-2.1.5 *Load Indicator* — A suitable load-indicating mechanism capable of showing the total tensile load carried by test specimen when held by the grips. This mechanism shall essentially free of inertia lag at the specified rate of testing shall indicate the load with an accuracy of ± 1 percent of indicated value, or better.

B-3 TEST SPECIMENS

B-3.1 Sheet, Plate, and Molded Plastics

B-3.1.1 The test specimens shall conform to the dimension shown in Fig. 1.

B-3.1.2 Test specimens shall be prepared by die cutting from materials in sheet, plate, slab, or similar form.

B-3.2 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. If the specimen exhibits such markings, it shall be discarded and replaced. If these flaws or imperfections are present in the new specimen, the die shall be inspected for flaws.

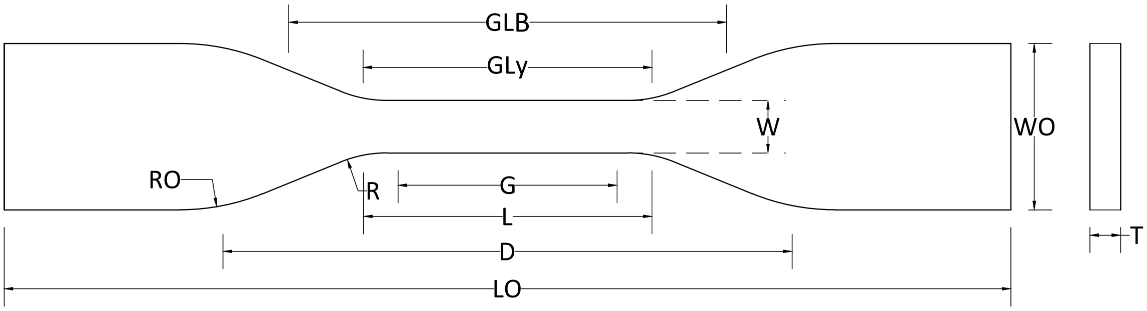


FIG. 1 TYPE IV DOG BONE SPECIMEN

Specimen Dimensions for type IV Dog Bone of Thickness, T, mm

All dimensions in millimetres

Description	*Dimension*	*Tolerance*
W – width of narrow section	6	± 0.5
L – length of narrow section	33	± 0.5
GL_y – gauge length for yield	33	± 0.5
GL_B – gauge length for break	50	± 0.5
W_O – width overall	19	± 6.4
L_O – length overall	115	No *Max*, No *Min*
G – gauge length	25	± 0.5
D – distance between grips	65	± 0.13
R – radius of fillet	14	± 1
R_O – outer radius	25	± 1

B-4 CONDITIONING

B-4.1 Conditioning

Specimens shall be tested once material has reached temperature equilibrium. The time required to reach temperature equilibrium may vary according to the manufacturing process, material type, and material thickness.

B-4.2 Test Conditions

Conduct tests in the standard laboratory atmosphere of 27 ± 2°C.

NOTE — A humidity requirement has intentionally been left out of test conditions due to the fact that polyolefins are not significantly affected by large fluctuations in humidity thereby making such a restriction unnecessary.

B-5 NUMBER OF TEST SPECIMENS

B-5.1 Test at least five specimens for each sample in the case of isotropic materials.

B-5.2 Test ten specimens, five normal to and five parallel with the principle axis of anisotropy, for each sample in the case of anisotropic materials.

B-5.3 Discard specimens that break at some obvious flaw and prepare new specimens for retest, unless such flaws constitute a variable to be studied.

B-6 SPEED OF TESTING

B-6.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the test. The rate of motion of the driven grip or fixture when the test apparatus is running idle may be used, if it can be shown that the resulting speed of testing is within the limits of variation allowed.

B-6.2 The test speed shall be 50 mm/mm for polyethylene geomembranes.

B-7 PROCEDURE

B-7.1 Measure the width and thickness of rigid flat specimens (*see* Fig.1).

B-7.2 Place the specimen in the grips of the test apparatus taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of grips to the machine. The distance between the end of gripping surfaces, when using flat specimens, shall be indicated in Fig.1. Tighten the grips evenly and firmly to degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

B-7.3 Set the speed of testing at the proper rate in accordance with **B-6.2**, and start the machine.

B-7.4 Record the load-extension curve of the specimen. Record the load and extension at the yield pointand the load and extension at the moment of rupture point.

B-8 CALCULATION

B-8.1 Tensile Yield Strength

Calculate the load corresponding to the yield point in N. Divide that load by the original minimum width of the specimen in mm. Express the result, in kN/m, and report it to three significant figures as tensile yield strength.

B-8.2 Tensile Break Strength

Calculate the load corresponding to the point of rupture (break), in N. Divide that load by the original minimum width of the specimen, in mm. Express the result, in kN/m, and report it to three significant figures as tensile break strength.

B-8.3 Percent Yield Elongation

Calculate percent elongation at the yield point by reading the extension (change in gauge length) at the moment the applicable load is reached. Divide that extension by the gauge length for yield listed in Fig. 1 (GL_y) and multiply by 100. Report percent yield elongation to the nearest 1 percent.

B-8.4 Percent Break Elongation

Calculate percent elongation at the break point by reading the extension (change in gauge length) at the moment the applicable load is reached. Divide that extension by the gauge length for break listed in Fig. 1 (GL_B) and multiply by 100. Report percent break elongation to the nearest 1 percent.

B-8.5 Calculate the average and standard deviation of the five specimens in each direction (where applicable) for the test results listed in **B-8.1** to **B-8.4**.

ANNEX C

[*Table* 1, *Sl No.* (v) *and Table* 2, *Sl No.* (vi)]

TEST METHOD FOR TEAR RESISTANCE

C-1 This test method covers of the determination of the tear resistance of HDPE geomembranes at very low rates of loading, 51mm/min, and is designed to measure the force to initiate tearing.

C-2 PRINCIPLE

The force to initiate tearing across a specific geomembrane specimen is measured using a constant rate of grip separation machine. The force necessary to initiate the tear is calculated from the load- time or load-displacement data.

C-3 APPARATUS

C-3.1 Testing Machine — A testing machine of the constant rate of crosshead-movement type and comprising essentially following:

C-3.1.1 *Fixed Member* — A fixed or essentially stationary member carrying one grip.

C-3.1.2 *Movable Member* — A moveable member carrying a second grip.

C-3.1.3 *Grips* — Preferably a set of self-aligning grips for holding the test specimen between the fixed member and the movable member of the testing machine. The grips shall minimize both slippage and uneven stress distribution.

C-3.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the testing machine. Fixed grips may be used, if extreme care is taken to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincide with the direction of pull through the centre line of the grip assembly.

C-3.1.3.2 Self-aligning grips are attached to the fixed and movable member of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen coincide with the direction of the applied pull through of the centre line of grip assembly.

C-3.1.4 *Drive Mechanism* — A drive mechanism capable of separating the movable member (grip) from the stationary member (grip) at a controlled velocity of 51 mm/min ± 5 percent.

C-3.1.5 *Load Indicator* — A suitable load-indicating mechanism capable of showing the total tensile load carried by test specimen held by the grips. The testing machine shall be essentially free from inertial lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 percent.

C-3.1.6 *Crosshead Extension Indicator* — A suitable extension indicating mechanism capable of showing the amount of change in separation of the grips (crosshead movement).

C-3.2 Thickness

Measure the specimen thickness by the test method as specified in Method A of IS 13162 (Part 3).

C-3.3 Die

A die having the dimensions shown in Fig. 2 shall be used to cut all specimens. The 90° angle shall be honed sharp with no radius or have minimum practical radius. The cutting edge of the die shall have a 5° negative rake and shall be kept sharp and free from nicks to avoid leaving ragged edges on the specimen. Wetting the surface of the sample and the cutting edges of the die with water may facilitate cutting. The sample shall rest on the smooth, slightly yielding surface that will not damage the die blade. Lightweight cardboard or a piece of leather belting is suitable. Care shall be taken that the cut edges of the specimen are perpendicular to its other surfaces and the edges have minimum of concavity.

C-4 TEST SPECIMEN

C-4.1 The test specimen shall be cut out with a die conforming to the dimension shown in Fig. 2 and shall not vary by more than 0.5 percent from these dimension. The cutting edges of the die shall be kept sharp and free from all nicks to avoid leaving ragged edges on the specimens.

C-4.2 Machine direction specimens are cut perpendicular to the machine direction and transverse direction specimens are cut perpendicular to the transverse direction.

C-4.3 Test a minimum of the five specimens each in the machine direction and in the transverse direction.

C-5 CONDITIONING

C-5.1 Conditioning

Condition the test specimen at 27 ± 2°C and 65 ± 5 percent relative humidity for not less than 40 h prior to test.

C-5.2 Test Conditions

Conduct test in the standard laboratory atmosphere 27 ± 2°C and 65 ± 5 percent relative humidity.

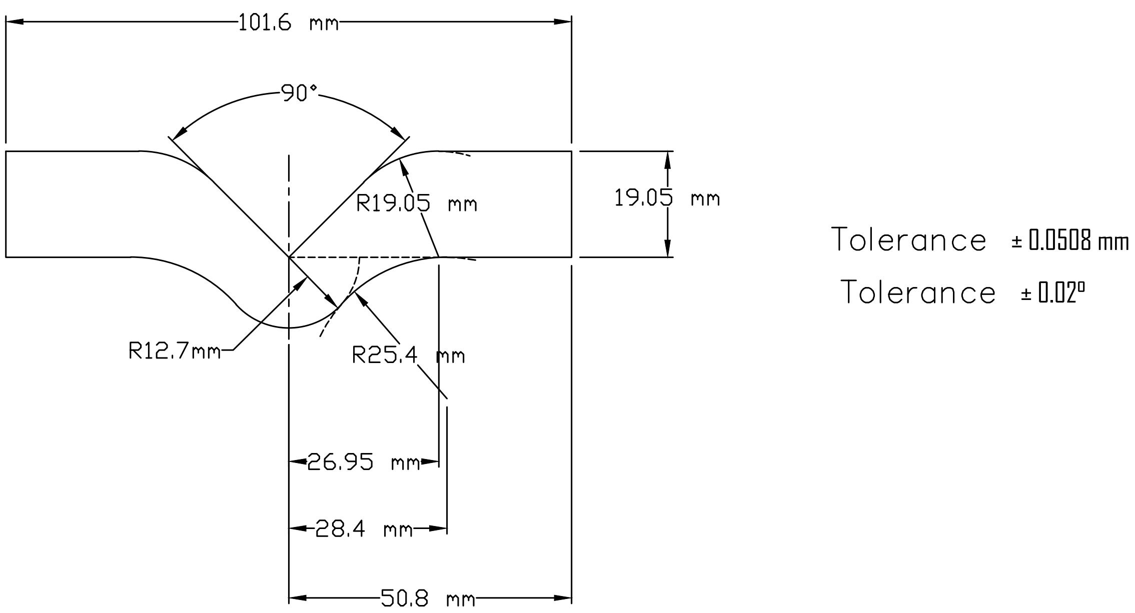


Fig. 2 Die For Tear Test Specimen

C-6 PROCEDURE

C-6.1 An initial jaw separation of 25.4 mm shall be used. The rate of travel of the power activated grip shall be 51 mm/min.

C-6.2 Measure the thickness of the specimen at several points in the notched area. Record the average thickness, in mm.

C-6.3 Place the specimen in the grips of the testing machine so that the long axis of the enlarged ends of the specimen in the line with the centre line of the grip assembly.

C-6.4 After complete rupture of the specimen, the maximum tearing load in newtons shall be recorded.

C-7 CALCULATION

Calculate the mean maximum resistance to tearing for all specimen tested in each principal direction of orientation.

ANNEX D

[*Table* 1, *Sl No.* (vi) *and Table* 2, *Sl No.* (vii)]

TEST METHOD FOR INDEX PUNCTURE RESISTANCE

D-1 SCOPE

This test method is used to measure the index puncture resistance of HDPE geomembrane.

D-2 PRINCIPLE

A test specimen is clamped without tension between circular plates of a ring clamp attachment secured in a tensile testing machine. A force is exerted against the centre of the unsupported portion of the test specimen by a solid steel rod attached to the load indicator until rupture of the specimen occurs. The maximum force recorded is the value of puncture resistance of the specimen.

D-3 APPARATUS

D-3.1 Tensile/Compression Testing Machine, of the constant-rate-of extension (CRE) type.

D-3.2 Ring Clamp Attachment, consisting of concentric plates with an open internal diameter of 45 ± 0.025 mm capable of clamping the test specimen without slippage. A suggested clamping arrangement is shown in Fig. 3. The external diameter is suggested to be 100 ± 0.025 mm. The diameter of the six holes used for securing the ring clamp assembly is suggested to be 8 mm and equally spaced at a radius of 37 mm. The surfaces of these plates can consist of grooves with O-rings or coarse sandpaper bonded onto opposing surfaces.

D-3.3 Solid Steel Rod, with a diameter of 8 ± 0.01 mm having a flat end with a 45° × 0.8 mm chamfered edge contacting the test specimen's surface (*see* Fig. 4).

D-4 TEST SPECIMEN

The test specimens shall be cut from the HDPE geomembrane and shall have a minimum diameter of 100 mm to facilitate clamping. If the 100 mm diameter sample is not available, smaller diameter may be taken provided sample is properly clamped. Take fixed numbers of 5 specimens.

D-5 CONDITIONING

Bring the specimens to moisture equilibrium in the atmosphere for testing (65 ± 5 percent relative humidity and 27 ± 2°C temperature). Equilibrium is considered to have been reached when the increase in the mass of the specimen, in successive weightings made at intervals of not less than 2 h, does not exceed 0.1 percent of the mass of the specimen.

D-6 PROCEDURE

D-6.1 Select the load range of the tensile/compression testing machine such that the rupture occurs between 10 and 90 percent of the full-scale load.

D-6.2 Centre and secure the specimen between the holding plates ensuring that the test specimen extends to or beyond the outer edges of the clamping plates.

D-6.3 Test at a machine speed of 300 ± 10 mm/min until the puncture rod completely ruptures the test specimen.

NOTE – The rate of testing specified is not an indication of the performance of the specimen for its end use.

D-7 CALCULATION

Calculate the average puncture resistance and standard deviation for all tests as read directly from the recording instrument.

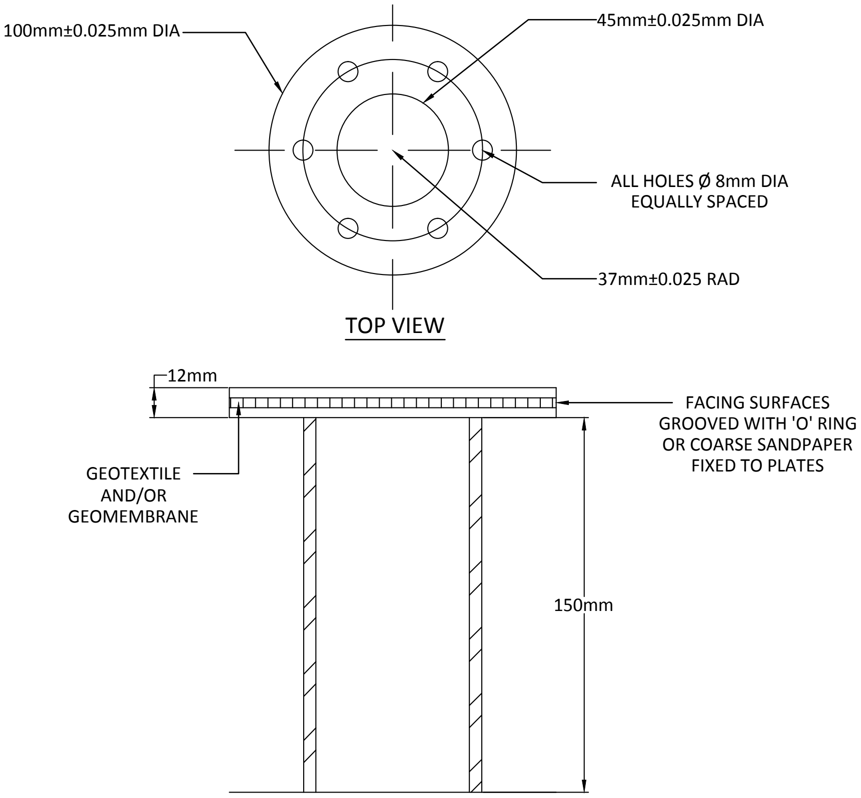


Fig. 3 Test Fixture Detail (Not to Scale)

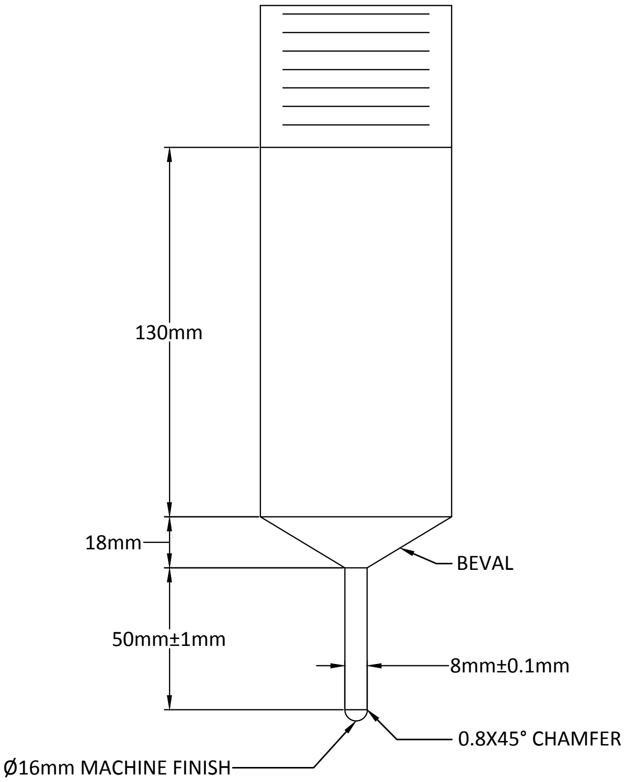


Fig. 4 Test Probe Detail (Not to Scale)

ANNEX E

[*Table* 1, *Sl No.* (vii) *and Table* 2, *Sl No.* (viii)]

METHOD FOR DETERMINATION OF LOW TEMPERATURE CRACK RESISTANCE TEST

E-1 PRINCIPLE

Specimens bowed in the shape of a loop are placed in a cooling chamber at -30°C and subjected to sudden folding under the impact of a free-falling mass of 500 g. The test specimen shall not break or is damaged.

E-2 APPARATUS

The following description is an example of a typical test apparatus design (*see* Fig. 5).

E-2.1 Impact Device, comprising the following elements:

E-2.1.1 *Specimen Holder*, permitting the fastening of one or more specimens on a platen by means of clamps (for example, leaf springs) to clench each specimen along its entire width (15 mm) and to secure 10 mm of each end of the loop (*see* Fig. 5) so that the length of the loop section subjected to folding is 40 mm.

The platen may be equipped with a mechanism (revolving type) that allows each specimen to be placed successively in the test position under the guide tube which guides the impact mass.

E-2.1.2 *Rigid Anvil*, connected to, or part of, the specimen holder and on which the specimen is brought

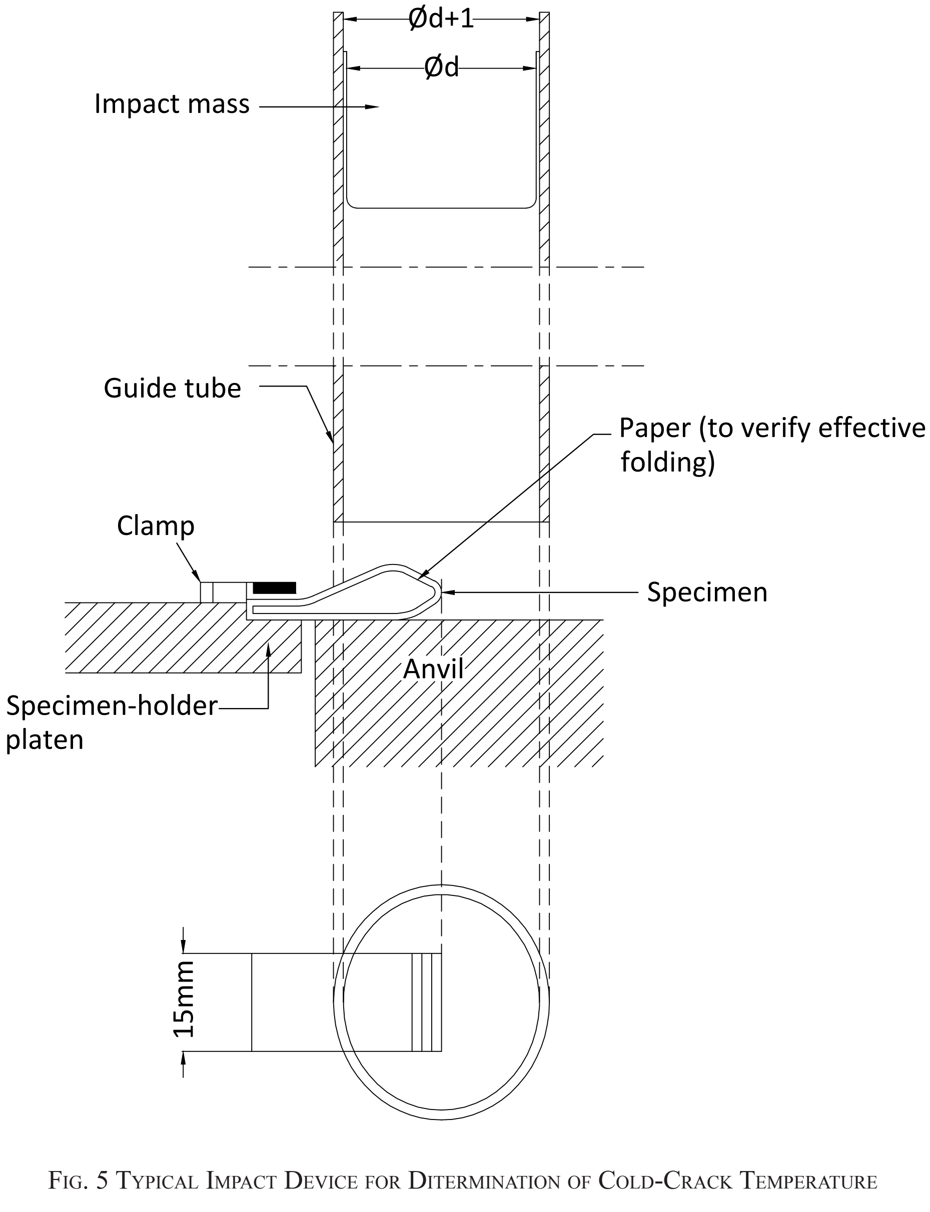


FIG. 5 TYPICAL IMPACT DEVICE FOR DITERMINATION OF COLD-CRACK TEMPERATURE

into the test position.

E-2.1.3 *Impact Mass*, 500 g, consisting of metal cylinders with a diameter of not less than 18 mm and not more than 29 mm, the edge of the lower face being slightly rounded.

E-2.1.4 *Guide Tube*, to guide the impact mass equipped at the upper end with a mechanism to release the mass (solenoid or mechanical trigger).

This tube, approximately 250 mm long and with a diameter 1 mm larger than that of the impact mass, shall be placed vertically above the specimen test position and shall be mounted so that the drop height, that is the distance between the base of the impact mass and the anvil, is 200 ± 2 mm.

E-2.1.5 *Holding Device*, to align the platen and the guide tube in such a position that the centre of the impact mass coincides with the edge of the flattened loop (20 mm from the clamp).

E-2.2 Cooling Chamber, to house the impact device allowing the temperature to be lowered in steps of 1°C, and able to maintain a temperature constant to within ±1°C.

E-2.3 Thermometer, graduated in 0.5°C, or thermocouple, with an accuracy of 0.5°C, placed in the cooling chamber in the proximity of the specimens.

E-3 SPECIMENS

E-3.1 Shape and Dimensions

The specimens shall consist of strips measuring 60 mm × 15 mm. Their edges shall be free from cuts, scratches and other imperfections.

E-3.2 Number of Specimens

Five specimens shall be taken with their long axis (60 mm) parallel to the machine (that is, longitudinal) direction, and 5 specimens with their long axis parallel to the transverse direction.

E-4 ATMOSPHERIC CONDITIONS FOR CONDITIONING AND TESTING

Condition the test specimens to moisture equilibrium from the dry side in the standard atmosphere of 65 ± 2 percent relative humidity and 27 ± 2°C temperature (*see also* IS 6359). When the specimens have been left in such an atmosphere so that both the faces are exposed to the standard atmosphere as far as possible for 24 h, they shall be deemed to have reached the state of moisture equilibrium.

E-5 PROCEDURE

E-5.1 Verify the alignment of the guide tube with respect to the position of the specimen on the platen.

E-5.2 Place the impact device containing the mounted specimens in the cooling chamber. When the impact device has reached equilibrium at the test temperature of minus 30°C (approximately 15 min), position the specimen below the guide tube. Release the impact mass, then reset it to its initial position. Repeat the operation for the other specimens, if any.

Take the platen out of the cooling chamber, remove the specimens and inspect them.

A specimen is deemed to be damaged or broken, if any trace of breaking is visible to the naked eye. This trace can be a point or a line, while total rupture may occur, with or without splintering. A whitish line at the fold may occur with certain types of pigmented or un-pigmented material, but this is not considered as a failure.

ANNEX F

[*Table* 1, *Sl No.* (viii) *and Table* 2, *Sl No.* (ix)]

DETERMINATION OF HYDROSTAIC RESISTANCE

F-1 PRINCIPLE

The hydrostatic resistance of the geomembranes shall be determined by Mullen-type hydrostatic tester.

F-2 APPARATUS

The testing machine shall permit the clamping of the material to be tested between two circular clamps about 76 mm in diameter having coaxial apertures of their centre 31.5 ± 0.5 mm in diameter. The surfaces of the clamps between which the specimen is to placed shall be concentrically grooved. The grooves shall be spaced 0.8 mm apart and of a depth not less than 0.15 mm. The grooves shall not start closer than 3.18 mm from the edge of the aperture. The lower clamping surface shall have a recession concentric to the aperture capable of accepting an O-ring having a cross-sectional diameter of 4.7 ± 0.1 mm.

The machine shall have means of applying hydraulic pressure to the underside of the clamped specimen until the specimen fails. The pressure shall be generated by means of a piston forcing water into the pressure chamber of the apparatus at the rate of 1.4 ± 0.1 cm^3/s. The machine shall be fitted with a pressure gauge maximum-reading type, with the scale divided to read kg/cm^2 units. Accuracy shall be 1 kg/cm^2 on readings from 0 to 60 kg/cm^2. When the gauge is calibrated, it shall be mounted in the same relative position as on the bursting tester.

NOTE — Any machine that operates on the above principle and maintains the specified displacement rate of 85 ml/min, and in addition possesses the opening in the upper clamping surface of 31.5 ± 0.5 mm, is a valid machine for this test.

F-3 TEST SPECIMENS

The test specimen cut from the geomembrane shall be of such size that the smallest dimension is at least 12.7 mm greater than the outside diameter of the ring-clamp mechanism of the testing machine.

F-4 PROCEDURE

Before clamping the specimen into the testing machine, bring the water level up flush with the top of the lower clamp so that no air pocket exist between the water surface and the geomembrane being tested. The temperature of the water shall be the same as the atmospheric temperature of the testing room. Increase the pressure steadily at a uniform rate of 1.4 ± 0.1 cm^3/s and take a trial reading at the first appearance of water through the geomembrane being tested. Make ten different determinations and take their average as the hydrostatic resistance of the geomembrane. Discard an isolated high or low result that is not repeated in duplicate when a consistent average has been obtained without the abnormal reading and substitute a retest.

ANNEX G

[*Table* 1, *Sl No.* (ix) *and Table* 2, *Sl No.* (x)]

DETERMINATION OF SEAM STRENGTH

G-1 APPARATUS

Tensile testing machine as described in Annex B of IS 2076.

G-2 PREPARATION OF TEST SAMPLES

A test piece 25 mm wide and approximately 100 mm in length shall be cut at right angles to the direction of the weld in such a manner that seam is equidistant from each end of the test piece. At least three test pieces shall be cut from weld piece.

G-3 PROCEDURE

Place the specimen in the jaws of the tensile testing machine with the seam centered between and parallel to the jaws and width of the specimen at right angles to the direction of application of force. Start the machine and observe by means of an autographic recording device the load necessary to slip the seam or rupture the specimen. The rate of extension of specimen between the jaws shall be 100 mm/min. If a specimen slips between the jaws, breaks or tears in a direction other than parallel to the seam or if for any reason due to faulty technique an individual measurement falls 20 percent below the median test results for the sample unit, discard and test another specimen until six specimens are checked. If the sample breaks other than a seam it shall be considered as unbreakable seam or the seam strength is 85 percent (*Min*) of the breaking strength of the same size specimens at the same conditions.

G-4 CALCULATION AND RESULTS

The seam strength of the specimen shall be calculated from breaking load, in kg. The mean value is to be reported.

ANNEX H

[*Table* 1, *Sl No.* (xiv) *and Table* 2, *Sl No.* (xv)]

UV RESISTANCE TEST

H-1 To determine the effect of UV radiation and weathering on the breaking strength, the HDPE geomembrane shall be exposed as given in **H-2** and **H-3**.

H-2 TEST CONDITION

The test shall be carried out with fluorescent UV- lamp Type B (313 nm or its equivalent).

The duration of the test shall be 144 h (that is, six days) in continuous mode.

The test cycle shall be: 8 h at 60 ± 3°C with UV-radiation alternating with 4 h at 50 ± 3°C with condensation. Irradiance level throughout the test shall be maintained at 0.63 (+0.03/-0) W/m^2.

H-3 TEST PROCEDURE

H-3.1 Determine the original average breaking strength of fabric as per the test method specified in Annex B.

H-3.2 Expose the specimens alternately to ultraviolet light and condensation in respective test cycle in continuous mode for total 144 h.

The type of fluorescent UV-lamp, the timing of the UV and condensation exposure and the temperature of the UV exposure and condensation shall be as specified in **H-2**.

H-3.3 Determine the average breaking strength of the fabric separately after UV exposure as mentioned above.

H-3.4 Determine the percent retention of original strength as follows:

Retention of original breaking strength, percent

$$= \frac{b}{a} \times 100$$

where,

a = Average breaking strength before UV exposure as obtained in **H-3.1**, and

b = Average breaking strength after UV exposure as obtained in **H-3.3**.

NOTES:

1 The UV source is an array of fluorescent lamps (with lamp emission concentrated in the UV range).

2 Condensation is produced by exposing the test surface to a heated, saturated mixture of air and water vapors, while the reverse side of the test specimen is exposed to the cooling influence of ambient room air.

ANNEX J

[*Table* 1, *Sl No.* (xv) *and Table* 2, *Sl No.* (xvi)]

TEST METHOD FOR STRESS CRACK RESISTANCE

J-1 PRINCIPLE

A dumbbell shaped notched test specimen of geomembraneis subjected to a constant tensile load in the presence of a surface-active agent and at an elevated temperature. The time to failure of the test specimen is recorded. The results of a series of such tests conducted at different stress levels are presented by plotting stress level against failure time for each stress level on a log-log axis.

J-2 APPARATUS

J-2.1 Blanking Die — A die suitable for cutting test specimens to the dimensions and tolerances shown in Fig. 6.

J-2.2Notching Device — A device or machine that can produce a consistent notch depth.

J-2.3 Blade — A single-edged razor made of carbon steel. The tip profile is that of an arrow rather than that of a chisel point. The sharpness of the point is critical to the cleanliness of the cut which affects the results of the test significantly.

J-2.4 Stress Cracking Apparatus — An equipment suitable for subjecting test specimens to a tensile stress of up to 13.8 MPa. The specimens shall be maintained at a constant temperature of 50 ± 1°C while being totally immersed in a surface-active agent. The solution shall be constantly agitated to provide a uniform concentration throughout the bath. One such apparatus is shown in Fig. 7.

J-3 REAGENT

The reagent shall consist of 10 percent surface-active agent with 90 percent water. The surface-active agent is Igepal CO-630 that is nonylphenoxy poly (ethyleneoxy) ethanol. The reagent shall be stored in a closed container. The reagent in the bath shall be replaced every two weeks to maintain a constant concentration.

J-4 TEST SPECIMENS

Five test specimens are cut from a representative sample of the geomembrane. All specimens shall be cut in the same direction.

J-5 PROCEDURE

J-5.1 Measure the thickness of each individual test specimen at its minimum cross-section to the nearest 0.013 mm. The variation in thickness shall not be greater than ±0.026 mm of the nominal thickness of the geomembrane.

J-5.2 Cut into each specimen a control imperfection (notch) on one surface as shown in Fig. 8. The depth of the notch shall produce a ligament thickness of 80 percent of the nominal thickness of the specimen.

J-5.3 Inspect the edge of the blade for scratches and burrs under normal vision prior to the cut. No single blade shall be used for notching more than 20 test specimens.

J-5.4 All notched test specimens are to be loaded to an equal stress level. The stress level applied to the test specimens shall be 30 percent of the room temperature yield stress of the geomembrane. The yield stress of the material shall be measured according to test method specified in Annex B. Five specimens shall be tested and the average value is used to calculate the applied force.

J-5.5 Calculate the tensile force to be applied to each individual specimen from the equation given below:

$$\text{Applied force, } F = (\sigma) \times (w) \times (t_L) \times (1/MA) \quad \ldots(1)$$

Where,

F= Force to be applied to achieve 30 percent of the yield stress;

Σ= 30 percent of yield stress of the material at room temperature;

w = Width of the neck of the test specimen;

t_L= Ligament thickness of the test specimen, that is, recommended to be 80 percent of the nominal thickness; and

MA = Mechanical advantage of the test apparatus, that is 3.0 for the apparatus shown in Fig. 10.

J-5.6 Fill the test bath with reagent, and adjust the temperature to 50 ± 1°C.

J-5.7 Attach the test specimens to the hooks of the test apparatus.

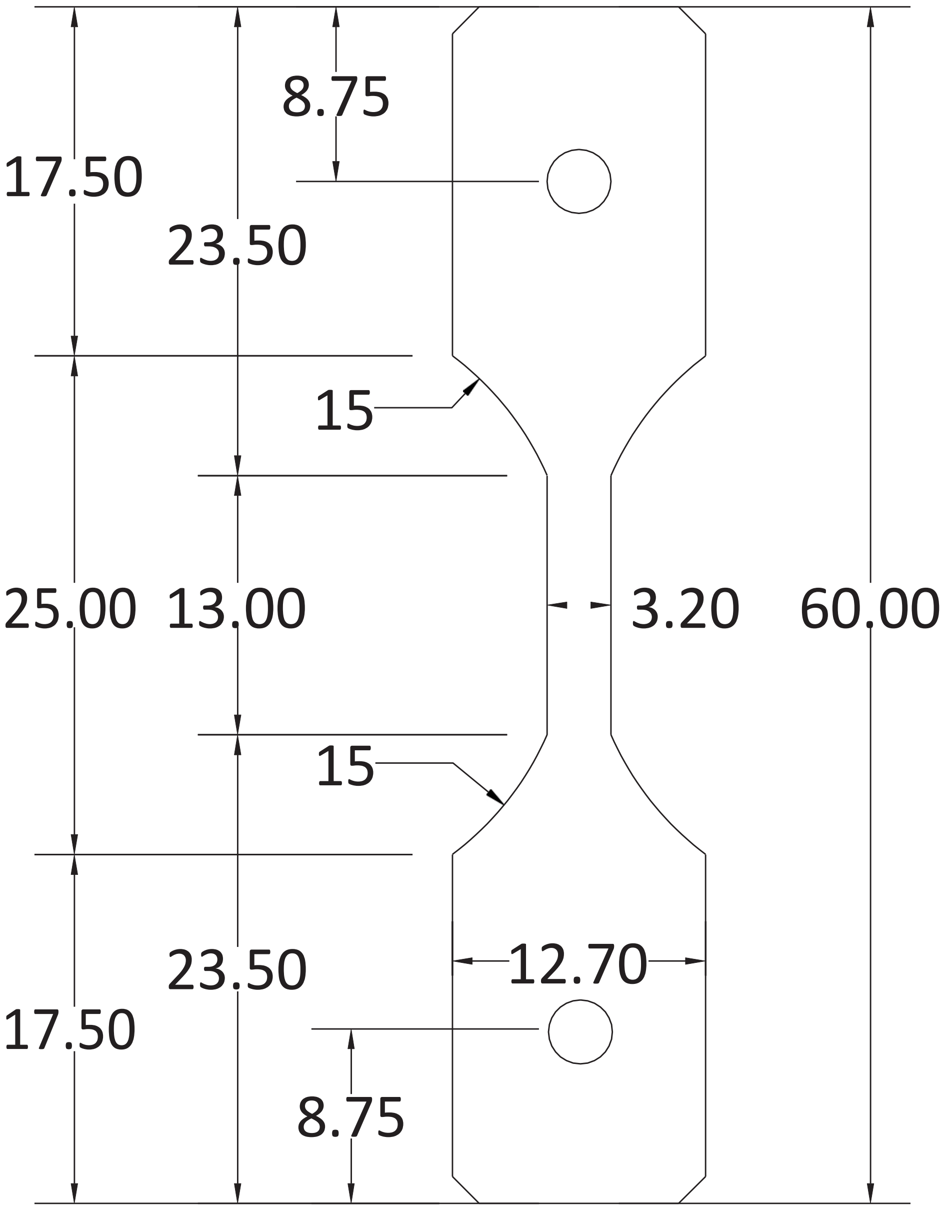
J-5.8 Adjust the distance between the lever arm and the switch to a dimension equal to 20 mm.

J-5.9 Immerse the test specimens and allow temperature equilibrium to be reached. The minimum time is 30 min.

J-5.10 Prepare the appropriated weight of lead shot (or other types) required for each individual test specimen according to J-**5.5**.

J-5.11 Load each individual specimen with its respective weight and record the elapsed time to failure to the nearest 0.1h.

J-5.12 Calculate the arithmetic mean of the failure time of all the five specimens.



All dimenaions in mm.

FIG. 6 DIMENSIONS OF TEST SPECIMEN

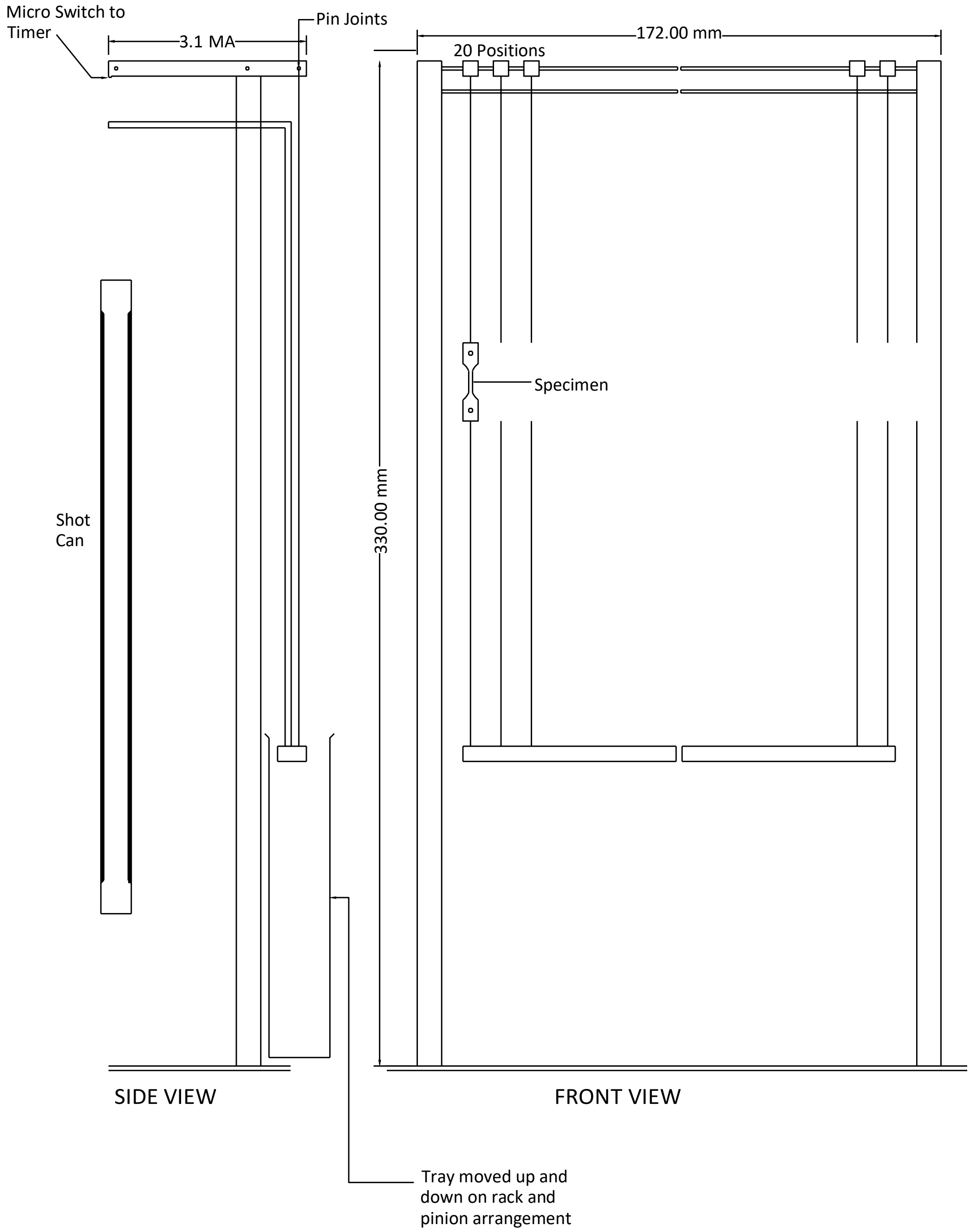
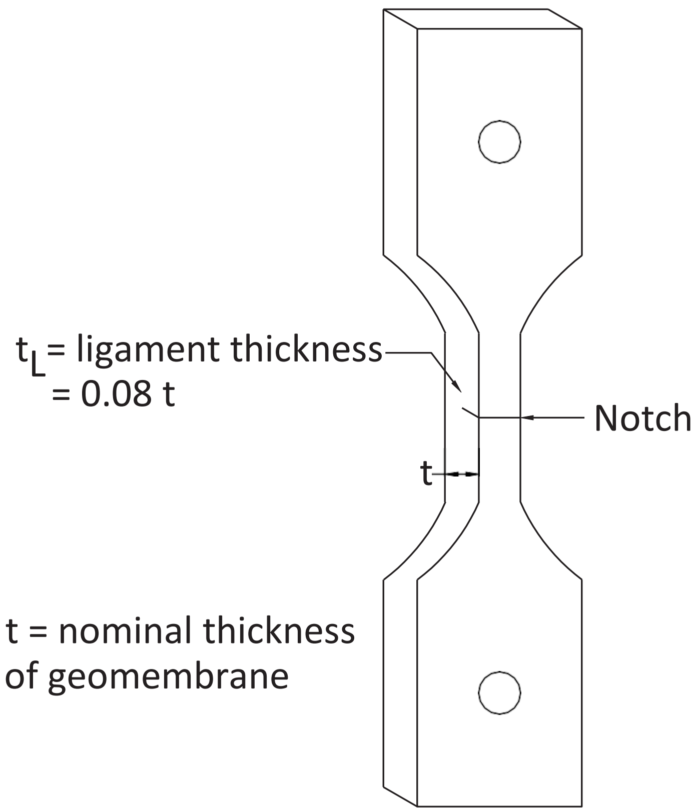
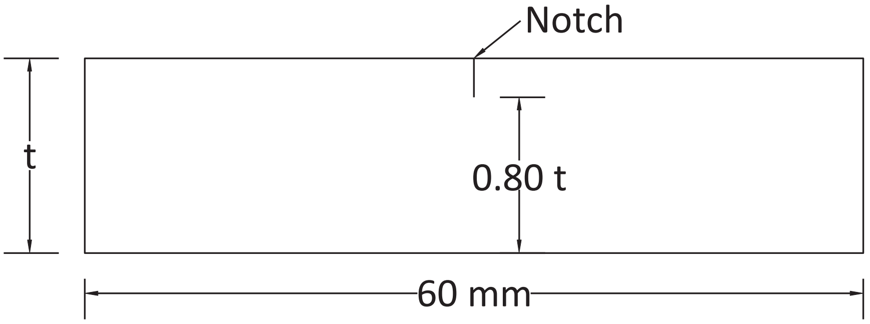


FIG. 7 APPARATUS FOR 20 TEST SPECIMENS



Front view of the cut test specimen



Side View of the Test Specimen

FIG. 8 FRONT AND SIDE VIEW OF THE NOTCHED TEST SPECIMEN FOR NCTL TEST

ANNEX K

[*Table* 2, *Sl No.* (ii and iii)]

TEST METHOD FOR MEASURING OF CORE THICKNESS FOR TEXTURED GEOMEMBRANE

K-1 Core average thickness of textured geomembrane is the measured distance between one surface to its opposite surface without stress of textured geomembrane.

K-2 TEST CONDITION

Prior to the test, specimens shall be conditioned to moisture equilibrium from dry side in standard atmosphere of 65 ± 5 percent relative humidity and 27 ± 2°C temperature as laid down in IS 6359.

K-3 TEST APPARATUS

K-3.1 Thickness gauge shall exert specified force of 0.56 ± 0.05 N with a base point and a free moving presser point whose axes are aligned to each other.

K-3.2 The thickness gauge point shall be made of hard material and shall be tapered at an angle of 60 ± 2° to the horizontal with the tip rounded to a radius of 0.8 ± 0.1 mm.

K-4 TEST SAMPLING

K-4.1 For the sample, take a full width sample of sufficient length excluding the inner and outer wrap of the roll.

K-4.2 Test specimen shall be cut in a randomly distributed pattern across the width including measurement within 20 cm of the both edge of the geomembrane roll. Ten samples of approximately 75 mm size shall be taken for testing.

K-5 TEST PROCEDURE

K-5.1 Testing shall be carried out in the test conditions as specified in **K-2**. The specified force shall be applied to the presser point on the base point (without specimen) and the scale shall show zero reading. Specimen shall be inserted after lifting the presser point and then allow the presser point to come slowly into contact with the test specimen. The test specimen shall be adjusted to locate the gauge point in to the indentation of the textured surface to obtain the local minimum thickness reading. Three measurements shall be taken on the test specimen and lowest of the 3 reading shall be recorded to the nearest 0.01 mm as thickness for the specimen.

K-5.2 The procedure given at **K-5.1** shall be repeated for remaining specimens.

K-5.3 Average of 10 readings of specimens obtained in **K-5.2** shall be calculated and shall be reported nearest to 0.01 mm.

ANNEX L

[*Table* 2, *Sl No.* (iv)]

TEST METHOD FOR MEASURING OF ASPERITY HEIGHT FORTEXTURED GEOMEMBRANE

L-1 Asperity is the individual projection of polyethylene that extend above the core surface of a textured geomembrane resulting in the textured surface.

L-2 TEST CONDITION

Prior to the test, specimens shall be conditioned to moisture equilibrium from dry side in standard atmosphere of 65 ± 5 percent relative humidity and 27 ± 2°C temperature as laid down in IS 6359.

L-3 TEST APPARATUS

L-3.1 Depth Gauge

The depth gauge shall consist of following three components:

a) Dial indicator,
b) A setting block, and
c) A contact point with extension.

L-3.1.1 Dial indicator shall be capable of measuring to a depth of at least 2.5 mm with an accuracy of ± 0.01 mm.

L-3.1.2 Setting block shall have a base dimension of 50 to 63.5 mmlong by12.7 to 20 mm wide and a height of 15 mm.

L-3.1.3 Contact point with extension is 1.3 mm in diameter with the tip tapered to a point.An extension of approximately 17 mm is required to achieve the necessary travel beyond the base surface of the setting block. The contact point shall protrude at least 10 mm below the setting block when not in use in order to ensure that a ‘’Zero’ setting is achieved.

L-4 TEST SAMPLING

L-4.1 For the sample, take a full width sample of sufficient length excluding the inner and outer wrap of the roll. Individual test specimen may be taken from this sample with aminimum diameter of 75 mm spaced such that a total of 10 asperity height determination can be made evenly across the sample.

L-4.2 For both side textured geomembrane, the surfaces shall be identified as below:

a) Side A — It shall correspond to the outside surface of the product on the parent roll.
b) Side B — It shall correspond to the inside surface of the product on the parent roll.

L-5 TEST PROCEDURE

L-5.1 Testing shall be carried out in the test conditions as specified in **L-2**. Depth gauge shall be placed on a flat rigid surface to zero the contact point with thebottom of the setting block.Geomembrane specimen being tested shall be placed on a flat rigid supporting surface to keep the specimen flat for the measurement.For both side textured geomembrane, the asperity height of side A shall be measured first.

L-5.2 Place the depth gauge on the surface of the textured geomembrane specimen with the long axis of the setting block perpendicular to the machine direction of the roll.Downward hand presser shall not be applied on the gauge to avoid compression of the asperities. Contact point of the depth gauge shall be brought into contact with the 'low spots' in between the asperities. Depth gauge shall be moved slightly on test specimen to obtain the local minimum reading. Repeat the above procedure within a radius of approximately 12 mm so that the total of three readings are obtained. The highest value of these three readings shall be recorded nearest to 0.01 mm.

L-5.3 The procedure given at **L-5.2** shall be repeated for remaining specimens. For double sided textured geomembrane, procedure given at **L-5.1** and **L-5.2** shall be repeated for side B.

L-5.4 Average of 10 readings of specimens obtained in **L-5.3** shall be calculated and shall be reported nearest to 0.01 mm. For double sided textured geomembrane, asperity height shall be reported for both the sides separately.

ANNEX M

(*Clause* 7.1)

PIN HOLES AND CRACKS

M-1 Examine for pin holes and cracks by viewing the surface of the HDPE geomembrane held under slight tension. Position of bright light source behind the HDPE geomembrane so as to clearly illuminate the surface without producing a glare in the observer's eyes. A pinhole is defined as any opening observed in the geomembrane under the condition specified above which is not visible when the geomembrane is viewed normally in average daylight or the equivalent thereof.

ANNEX N

(*Foreword*)

GUIDELINES FOR INSTALLATION OF HDPE GEOMEMBRANE

N-1 PREAMBLE

N-1.1 The primary function of geomembrane applied in ponds/reservoirs is to prevent loss of water due to seepage. The successful performance of geomembrane is based on a good quality material, installation and appropriate design of ponds/reservoirs.

N-1.2 To improve the service lifetime of geomembrane, it is essential that the geomembrane are placed on the pond/reservoir surface according to the dimensions and contours of the pond/reservoir ensuring full contact with the sub-grade. To achieve this onsite laying, joining and fixing is imperative.

N-2 LOGISTICS

Geomembrane are packed and transported by appropriate means to protect the geomembrane and avoid any type of damage. Rolls of geomembrane are loaded manually/with a crane and tie beam and can be unloaded in a similar manner at the destination. Use of hooks shall be avoided for loading and unloading of the geomembrane at site.

N-3 STORAGE AT SITE

N-3.1 The geomembrane shall be stored so as to be protected from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, excessive heat or other damage. The rolls shall be stored on a prepared surface and to be stacked not more than three rolls.

N-3.2 The owner of the site where the geomembrane is to be installed shall provide storage space in a location sufficiently near the sub-grade to be lined to minimize any additional handling.

N-3.3 The storage area shall be protected from theft, vandalism, vehicular traffic and any other source which could create potential damage to the liner.

N-4 EARTHWORK AND SITE PREPARATION

N-4.1 SITE CONSIDERATIONS

N-4.1.1 The site selected for pond/reservoir shall not be within the path so that, it obstructs or impinge the flow of the natural course of the water, rain fed *Nallah* or a stream as well as in the pathway of concentrated surface runoff from the hills or elevated grounds upstream of the pond/reservoir, as there are chances of underground seepage of water into the pond/reservoir and geomembrane is subjected to upliftment.

N-4.1.2 The proposed pond/reservoir site shall not be natural pit, a well or stone mines.

N-4.1.3 The selected site shall be free from hard rocks/ Murrum, a natural water source, mountain, etc.

N-4.1.4 The proposed site shall be free of any decomposable organic materials/vegetation as it can result in upliftment due to generation of gases beneath the geomembrane.

N-4.2 Design and Sub-grade Preparation

N-4.2.1 The excavation of the pond/reservoir shall be done by means of a JCB or pock lainmachine.

N-4.2.2 The slope to bed ratio (V: H) shall be 1:1.5 minimum.

N-4.2.3 The embankments constructed shall be stable, as the unstable embankments will collapse resulting into tensile or tear failure of geomembrane.

N-4.2.4 The top width of the embankment shall be at least 1.5 m wide.

N-4.2.5 Sub-grade surface shall be levelled and made free of undesirable angular and sharp fragments, foreign and organic matter, stones and pebbles, as the presence may lead to cause pinholes and or puncture the geomembrane.

N-4.2.6 Soil sterilization may be necessary to kill roots certain types of grasses by using an effective sterilant/ chemical, however the sterilant or the chemical used shall not be detrimental to the liner and shall be applied in accordance with the geomembrane manufacturer's recommendations.

N-4.2.7 The bed and slopes of the constructed pond/ reservoir shall be inspected for burrows of crab's rodents, etc. All such burrows shall be emptied by removing the crabs and rodents and disposed off to a safe site away from the pond/reservoir site.

N-4.2.8 The empty burrows and potholes (cavity between the stones) on the bed/slope of pond/reservoir shall be filled with soil. Thereafter it shall be compacted and the entire area shall be cleaned and levelled. The entire area shall be uniform and smooth.

N-4.2.9 A layer of soft soil shall be applied and the top layer of soft bed and slope shall be compacted by water showering at least 90 percent of proctor density by vibro compaction equipment or by any other suitable equipment or manually.

N-4.2.10 The compaction shall be achieved at least up to a depth of 300 mm from the final sub grade level of inside of the pond.

N-4.2.11 Perfect compaction and levelling of bed and slopes will give good support to the geomembrane.

N-4.2.12 Inlet and outlet structures shall be properly designed, faulty design and construction of inlet and outlet structures shall result in flooding or overtopping of embankments damaging the geomembrane.

N-5 ANCHOR TRENCH

N-5.1 For the purpose of anchoring the geomembrane, an anchor trench of 1 feet × 1 feet × 1 feet shall be excavated at a distance of 80 to 100 cm away from the inside edge of the top of the embankment.

N-5.2 Rounded corners shall be provided in the trench to avoid sharp bends in the geomembrane. It is imperative that the anchor trench is complete in all respects before lining work is undertaken to ensure the speed of lining and schedule.

N-5.3 The anchor trench shall be back filled after filling the pond, till then filled sand bags shall be kept as counter weight.

N-6 COMMENCEMENT OF GEOMEMBRANE INSTALLATION WORK

N-6.1 Before starting the geomembrane installation the contractor shall issue a certificate of satisfactory site conditions, to enable to commence geomembrane installation work.

N-6.2 Chain linked fencing shall be put around the pond/reservoir to prevent stray entry of men and animals to protect any damage to the geomembrane.

N-7 GEOMEMBRANE LAYING OPERATIONS

N-7.1 While laying the geomembrane precaution shall be taken to avoid any damage to the lining system.

N-7.2 The reservoir area shall be declared as a ‘NO SMOKING ZONE’ and all personnel shall wear flat rubber soled foot wear (similar to bathroom slippers).

N-7.3 The method of unrolling the geomembrane panels shall be such that it shall not cause scratches or crimps in the geomembrane and any damage to the sub-grade surface.

N-7.4 Geomembrane panels shall be placed properly on the bed and the slopes with an overlap of 50 to 75 mm for field seaming, or as specified, but not less than 50 mm.

N-7.5 At corners of the pond/reservoir the panels shall be properly matched and laid according to the size and geometry of corners of the embankment slopes (commonly the shape shall be an inverted triangle) and joined with adjacent liner panels on the slope.

N-7.6 Counter weight of filled sand bags along the edges of geomembrane panels and toe of the bunds shall be provided in order to minimize the risk of flow of wind under the panels.

N-7.7 The geomembrane interface where seams are to be made shall be clean and free from dust.

N-7.8 Geomembrane shall not be laid during rains, any precipitation, in the presence of excessive moisture, in an area of standing water, or during high winds, fog, dew, etc.

N-7.9 Any area of panel seriously damaged shall be marked and repaired.

N-7.10 Geomembrane deployment shall stop in excessive temperatures since this will result in imperfect seaming.

N-8 FIELD SEAMING OF GEOMEMBRANE

The fundamental mechanism of seaming geomembrane sheets together is to temporarily reorganize the polymer structure (by melting or softening) of two opposing surfaces to be joined in a controlled manner so that, after the application of pressure, results in the two sheets being bonded together and the joined sheets shall perform as one single geomembrane sheet. Therefore field seaming is a very important and crucial operation and any negligence on this part shall compromise severely the performance of geomembrane system.

N-9 SEAMING OPERATIONS OF GEOMEMBRANE

N-9.1 Seams shall be oriented parallel to the slope that is oriented down, not across the slope.

N-9.2 Wherever, odd shaped geometric location or corners are identified, the field seams shall be minimized.

N-9.3 Horizontal seam shall be located on the base of the slope, not less than 1.50 m from the toe of the slope.

N-9.4 When seaming, panels shall be adjusted to ensure that the seams are aligned with the fewest possible number of wrinkles and ‘fish mouths’.

N-9.5 Seaming shall extend to at least 20 cm into the anchor trench. While welding a seam, proper overlap shall be monitored and maintained.

N-9.6 A pressure type joint, employing the SS or HDG flats, neoprene seals, and SS or HDG bolts and nuts shall be used to seal the junctions, inlet and outlet structures and pipes.

N-9.7 Seam area shall be inspected to assure that it is clean and free of moisture, dust, debris of any kind.

N-9.8 Welding technicians shall periodically check the machine operating temperature and speed and shall record this information.

N-10 SINGLE FUSION HOT AIR WELDING

In single fusion hot air welding, a device consisting of a resistance heater, a blower and a temperature controller is used to blow hot air between the two geomembrane sheets in the overlap. The hot air at 400 to 450°C shall melt the geomembrane opposing surfaces.

Immediately following the melting of surfaces, pressure is applied to the seamed area to bond the two sheets using a roller.

N-11 FACTORS AFFECTING THE FIELD SEAMS

N-11.1 Many factors contribute to the quality of field seam such as ambient temperature, moisture, wind, dust and quality of the field personnel.

N-11.1.1 *Ambient Temperature*

Field seaming shall be performed when weather conditions are favorable. Seaming below 5°C and above 40°C may result in a decrease in the overall quality of installation.

N-11.1.2 *Moisture*

Moisture caused due to precipitation or high humidity is likely to result in improper bonding resulting in failure of seams. Therefore the surface of panel in seaming shall remain dry at all times.

N-11.1.3 *Wind*

Winds causing displacement of geomembrane panels may interfere with the proper alignment of seams, resulting in wrinkles or 'fish mouths'.

N-11.1.4 *Dust*

The geomembrane panels shall be maintained in a broom clean condition with no dust allowed on or near the seaming areas.

N-11.1.5 *Quality of Field Personnel*

The critical parameters for the hot air fusion welding machine are temperature and speed which shall be strictly maintained. Therefore, well trained professionals/ technicians shall be employed for field seaming. Excessive melting weakens the geomembrane and inadequate melting results in poor strength. Hence a well-trained technician shall be able to apply adequate melting and pressure making proper seams.

N-12 FIELD TESTING OF SEAMS

N-12.1 To ensure the quality of seams, it is necessary to have a check on the seams at site by visual and manual methods to identify any defective field seams involving presence of unbounded or open seams, fish mouth created due to wrinkles and restraints, burning of liner due to excessive heat during thermal bonding.

N-12.2 Any one of the following advance test methods can be performed for testing of seams:

a) Air lance method,
b) Mechanical point stress/pick test, and
c) Vacuum box testing.

N-12.2.1 *Air Lance Method*

The air lance method uses a jet of air at approximately 350 kPa pressure coming through an orifice of 5 mm diameter. It is directed beneath the upper edge of the overlapped seam to detect unbounded areas. When such an area is located, the air passes through causing inflation and fluttering in the localized area. The audible sound also changes when unbounded areas are encountered. This method works on relatively thin, less than 1.00 mm, flexible geomembrane, but it works only if the defect is open at the front edge of the seam where the air jet is directed.

N-12.2.2 *Mechanical Point Stress/ Pick Test*

The mechanical point stress or the pick test uses a dull tool (such as a blunt screw driver) under the top edge of the seam. With care, an installer can detect an unbounded area which is easier to separate than a properly bonded area. It is a rapid test that obviously depends completely on the care and sensitivity of the person doing it. Detectibility is similar to that using the air lance and both are very operator dependent.

N-12.2.3 *Vacuum Box Test*

A vacuum box assembly consisting of a rigid housing with a transparent window and having a soft rubber gasket attached to the bottom porthole or assembly and a vacuum gaugeshall be used. Soap solution in plastic bucket with a mop shall be made available. The excess sheet overlap if any, shall be properly trimmed away. Then a strip of geomembrane of length 300 mm shall be wetted by the length of box with the soap solution. The box shall be placed over the wetted area and compressed. Create a vacuum of 0.15 kg/cm^2 to 0.35 kg/cm^2. Care shall be taken to ensure that a leak proof seal is created. Vacuum shall be maintained for a sufficient time that is for a period of approximately 10 to15 s. Examine the geomembrane through the viewing window for presence of any soap bubbles. In case no such soap bubbles appear after 10 to15 s, close the vacuum valve and open the bleed valve. Thereafter move the box over the next area adjoining the tested area with a minimum 75 mm overlap. Repeat the process as described above. In case animated soap bubbles appear, all such areas shall be marked, repaired and then retested.

N-13 POST INSTALLATION PRECAUTIONS

N-13.1 If there is no proposal of fixing cover system over the geomembrane, the pond/reservoir shall be filled as soon as possible after installation work to ensure that the geomembrane fully adheres to the sub-grade surface.

N-13.2 The geomembrane shall be loosened from the anchor trench, wherever it is found to be stretched, after filling the pond/reservoir.

N-13.3 The inlet pipe through which liquid intake is being done in the pond/reservoir where liquid falls continuously at a particular area, such point shall be fixed with an extra piece of geomembrane to avoid damage at that particular point due to force of the drop.

N-13.4 A shade net shall be laid at corner of the pond/ reservoir. There are chances of some reptiles entering into the pond, in spite of fencing. These reptiles can't come out of the pond/reservoir as they cannot crawl on the geomembrane. Hence, to prevent damage to the geomembrane, shade nets shall be installed at the corners over the geomembrane.

N-13.5 If a submersible pump is used to draw the liquid from the pond/reservoir than an anti-vibration mounting or a float shall be used under the submersible pump.

ANNEX P

(*Foreword*)

COMMITTEE COMPOSITION

Geosynthetics Sectional Committee, TXD 30

Organization	*Representative(s)*
The South India Textile Research Association Council, Coimbatore	Dr A. N. Desai (***Chairman***)
Ahmedabad Textile Industry's Research Association, Ahmedabad	Shrimati Deepali Plawat Shri Jigar Dave (*Alternate*)
Best Geotechnique Pvt Ltd, Mumbai	Shri Satish Naik
Central Coir Research Institute, Alappuzha	Dr D. Anita Ravindranath Shrimati Sumy Sebastian (*Alternate*)
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Central Water Commission, New Delhi	Representative
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DKTE Centre of Excellence in Nonwovens, Ichalkaranji	Shri Aniket S. Bhute
Ganga Flood Control Commission, Patna	Shri A. K. Sinha Shri Manoj Kumar (*Alternate*)
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Kusumgar Corporates, Mumbai	Shri Y. K. Kusumgar Dr M. K. Talukdar (*Alternate*)

Organization	*Representative(s)*
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Megaplast India Pvt Ltd, Daman	Shri C. V. Rajesh Shri Hemendra Behera (*Alternate*)
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